(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 466 362 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **91305787.3**

(51) Int. Cl.[5]: **F26B 7/00**

(22) Date of filing: **26.06.91**

(30) Priority: **29.06.90 JP 172948/90**

(43) Date of publication of application: **15.01.92 Bulletin 92/03**

(84) Designated Contracting States: **AT CH DE FR GB IT LI**

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(54) Method and apparatus for drying powdered or granular materials.

(57) The powdered or granular materials to be dried are heated to the prescribed temperature with electromagnetic waves such as microwave, etc. under a reduced pressure and then dried to the prescribed moisture percentage while passing through a heat insulating process. An apparatus for it is provided with a reduced pressure drying tank (1) having an electromagnetic wave generator (2) of microwave, etc. and a main drying tank (30) communicated with the said reduced pressure drying tank (1) and having a heat preserving heater (33), at least the said reduced pressure drying tank (1) being constituted in a way to be depressurized by a suction air source (20).

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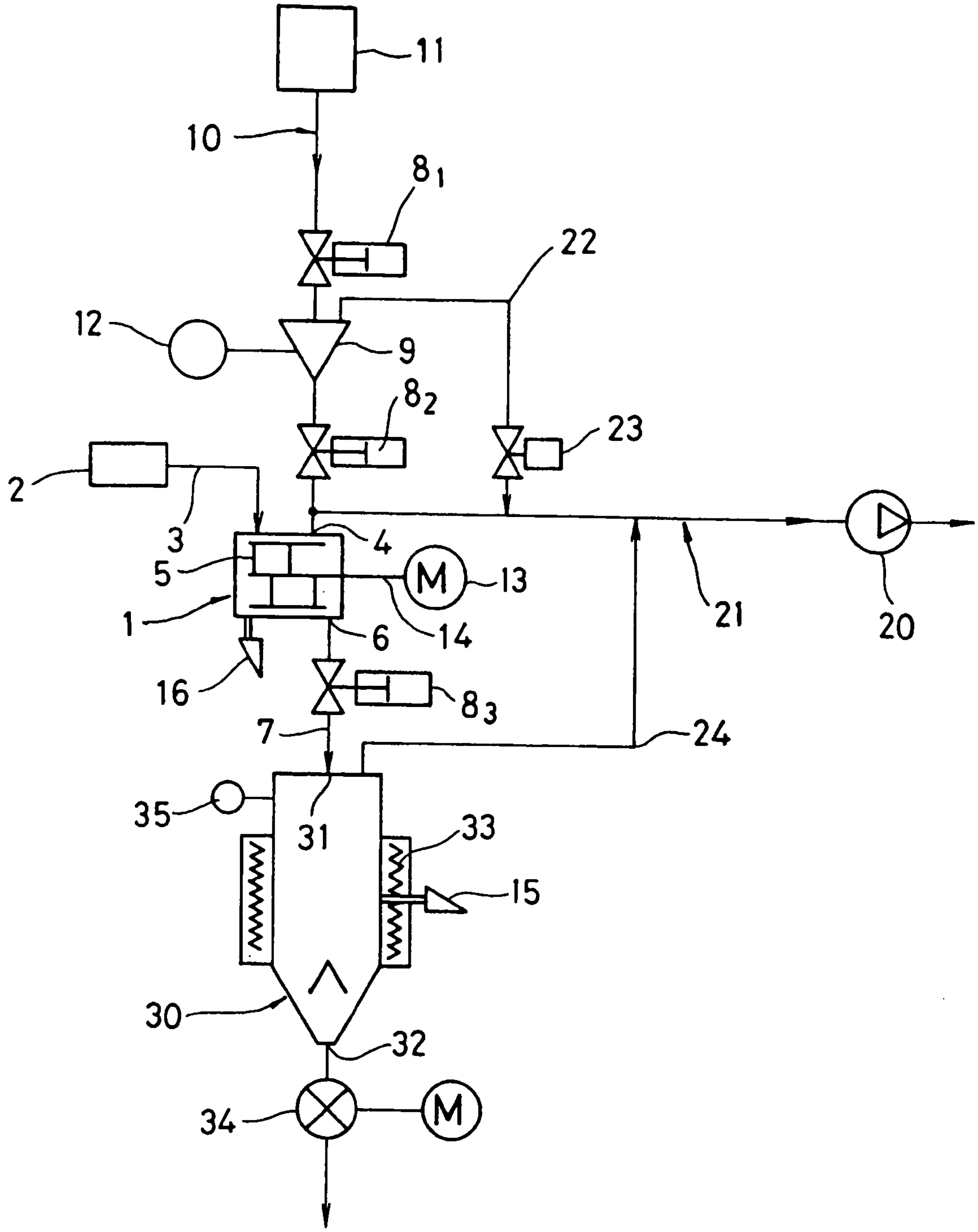

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FIG. 1

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a method and an apparatus for drying powdered or granular materials such as synthetic resin materials, processed foot materials, chemical materials for medical use, etc. by submitting them to dielectric heating by means of electromagnetic waves such as microwave, high frequency, etc.

Prior Art

Conventionally, a drying method by hot air is widely known as drying method of this kind of powdered or granular materials. As concrete construction of that method, one which is indicated in Fig. 4 is known for example in addition to the so-called hopper dryer provided with a blower, a heater and a hopper.

The system indicated in Fig. 4 consists of a preliminary heating tank A comprising a stirring blade C which agitates the powdered or granular materials supplied through the material inlet B while heating them, a main drying tank F which receives the materials from the preliminary heating tank A through the material inlet G via a rotary feeder E connected to the material outlet D side of the preliminary heating tank A and heats them with the thermal energy of a heater H, a dehumidifying unit J which is provided on the upstream side of the said heater H and supplies dehumidified air, a piping T which returns the exhaust air of the main drying tank F through the exhaust port K to the heating port L of the preliminary heating tank A via a line filter N, a blower O and a heater H_1, and a piping R which returns the exhaust air of the preliminary heating tank A to the inlet Q of the regenerating line of the dehumidifying unit J through the exhaust port P.

Therefore, the powdered or granular materials submitted to preliminary heating in the preliminary heating tank A are dried in the main drying tank F and the powdered or granular materials thus dried to the prescribed moisture percentage are discharged from the material outlet S of the main drying tank F to the subsequent process. The preliminary heating tank A also serves as a crystallizing tank in the case of such powdered or granular materials as non crystallized polyethylene terephthalate, etc.

However, according to the conventional example mentioned above, the dehumidified air from the dehumidifying unit J is heated by the heaters H, H_1 respectively and the heated air is sent by the blower O to the preliminary heating tank A to heat the powdered or granular materials to the desired temperature (and to crystallize them in the case of such powdered or granular materials as non crystallized polyethylene terephthalate, etc.). After that, the heated air is sent to the main drying tank F to dry the powdered or granular materials to the prescribed moisture percentage. In this way, the heated air is made to pass through the tanks A, F as medium.

For that reason, in the conventional example, not only a large amount of electric power was consumed for the heating of air to raise the temperature of powdered or granular materials in the preliminary heating tank A, for the heating of air to regenerate the adsorbent in the dehumidifying unit J and for driving the blower O to send heated air but also the running cost was high because of a lower energy efficiency due to radiation loss in the sending route of heated air such as piping T, piping R, etc.

Moreover, the presence of the line filter N in the middle of the piping T also served to increase the system cost.

In addition, this conventional example was not suitable to such powdered or granular materials as turn yellow by oxidation when heated in the air as nylon.

The present invention is intended to solve all of the problems mentioned above by heating the powdered or granular materials to the prescribed temperature by means of electromagnetic waves such as microwave, etc. under a reduced pressure (and crystallizing them in the case of such powdered or granular materials as non crystallized polyethylene terephthalate, etc.) and, after that, drying them to the prescribed moisture percentage passing through a heat insulating process.

SUMMARY OF THE INVENTION

One of the objects of the present invention is to provide a drying method of powdered or granular materials and an apparatus for it, namely a method for drying powdered or granular materials to be dried through a heating process which heats the powdered or granular materials to the prescribed temperature by means of electromagnetic waves such as microwave, etc. under a reduced pressure and a heat insulating process which preserves the heat and performs final drying after that and an apparatus for implementing that method provided with a reduced pressure drying tank having an electromagnetic wave generator and a main drying tank communicated with the reduced pressure drying tank and having a heat preserving heater, at least the said reduced pressure drying tank being constituted in a way to be depressurized by a suction air source, at least inside the reduced pressure drying tank the radiation loss being comparatively small compared with the drying system by hot air because the apparatus is not designed for circulating air as medium by blowing through a piping as in the conventional drying system by hot air, thus providing a high energy efficiency.

Another object of the present invention is to pro-

vide (an apparatus capable of providing) a higher energy efficiency with a smaller radiation loss compared with the above by drying the powdered or granular materials under a reduced pressure in the heat insulating process in addition to the heating process and also in the main drying tank in addition to the reduced pressure drying tank, the apparatus not being designed for circulating air as medium by blowing through a piping as in the conventional drying system by hot air.

The still another object of the present invention is to provide (an apparatus capable of) attenuating the yellowing of the powdered or granular materials compared with the conventional apparatus by submitting the powdered or granular materials to heating and drying by heat insulation in the case of such powdered or granular materials as turn to yellow by oxidation when heated in the air as nylon.

A further object of the present invention is to provide (an apparatus capable of) further shortening the drying time by performing drying in a reduced pressure atmosphere in the case of powdered or granular materials as nylon as mentioned before and by setting the heating and the preservation temperature at a higher level compared with the conventional example.

A still further object of the present invention is to facilitate maintenance control and enable miniaturization of drying system with a smaller number of component parts because there is no need of making regeneration of line filter and dehumidifying unit as in the conventional example shown in Fig. 4 thanks to the above-mentioned construction.

An additional object of the present invention is to make it possible to accelerate the drying speed or improve the final moisture percentage by providing separate suction air sources for the reduced pressure drying tank and the main drying tank and producing different states of pressure reduction for the reduced pressure drying tank and the main drying tank as mentioned earlier.

Other objects, features and benefits of the present invention will become clearer with the following explanation:

To achieve the above objects, the present invention adopts a method for drying powdered or granular materials to be dried through a heating process which heats the powdered or granular materials to the prescribed temperature by means of electromagnetic waves such as microwave, etc. under a reduced pressure and a heat insulating process. In this case, it is better to dry the powdered or granular materials under a reduced pressure in the heat insulating process.

As concrete construction for implementing the above method, the drying system is provided with a reduced pressure drying tank having an electromagnetic wave generator which performs dielectric heating of the powdered or granular materials supplied through the material inlet and a main drying tank communicated with the reduced pressure drying tank and having a heat preserving heater, at least the said reduced pressure drying tank being constituted in a way to be depressurized by a suction air source.

In this case, the main drying tank may be constituted in a way to be depressurized with a suction air source. Separate suction air sources may be provided for the reduced pressure drying tank and the main drying tank. It is also possible to provide a preliminary reduced pressure tank on the upstream side of the reduced pressure drying tank so that the preliminary reduced pressure drying tank may also be depressurized by the suction air source. At least the suction air source of the reduced pressure drying tank may be used commonly to the preliminary reduced pressure drying tank.

The powdered or granular materials to be dried are heated to the prescribed temperature with electromagnetic waves such as microwave, etc. under a reduced pressure in either the heating process or the reduced pressure drying tank.

After that, the heated powdered or granular materials are dried to the prescribed moisture percentage while being heat insulated in either the heat insulating process or the main drying tank.

If the heating of powdered or granular materials under a reduced pressure is performed not only in the heating process or the reduced pressure drying tank but also in the heat insulating process or the main drying tank, it is possible to prevent yellowing of powdered or granular materials due to oxidation and prevent staining of powdered or granular materials by external air because no blowing of hot air is used as medium as in the hot air drying system of the conventional example.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a process chart of the 1st embodiment. Fig. 2 is a process chart of the 2nd embodiment. Fig. 3 is a process chart of the 3rd embodiment. Fig. 4 is a process chart of the conventional example.

DETAILED DESCRIPTION OF THE INVENTION

A description of the 1st embodiment according to the present invention as shown in Fig. 1 is given hereunder.

1 is a reduced pressure drying tank of closed construction, with a waveguide 3, etc. of an electromagnetic wave generator 2 which produces microwaves, far infrared rays and other electromagnetic waves connected to the top plate and a material inlet 4 provided at another point of that top plate. The powdered or granular materials such as synthetic resin material, etc. supplied into the reduced pressure drying tank 1 through the material inlet 4 are submitted to dielectric

heating to the desired temperature by irradiation of electromagnetic waves from the said electromagnetic wave generator 2 while being agitated with the rotation of an agitating means 5 provided inside the said reduced pressure drying tank, under a reduced pressure as described later, and the hot powdered or granular materials are fed into a main drying tank 30 through a communicating tube 7 communicated with a material outlet 6 of the reduced pressure drying tank 1. 8_3 is a material valve.

A material piping 10 is connected to the material inlet 4 of the reduced pressure drying tank 1 and this material piping 10 is provided to the upstream side with a material valve 8_2 a preliminary reduced pressure tank 9 and a material valve 8_1 and a supply source of materials 11 in order.

An exhaust pipe 21 is branched from the said material piping 10 between the material inlet 4 and the material valve 8_2 and a suction air source 20 such as diaphragm pump, etc. is connected to this exhaust pipe 20 so that the pressure inside the reduced pressure drying tank 1 may be reduced to under the atmospheric pressure (100 - 200 Torr in the embodiment, but not limited to this value), by operating this suction air source 20. Moreover, a branch exhaust pipe 22 is connected halfway on the exhaust pipe 21 and the other end of this branch exhaust pipe 22 is connected to the said preliminary reduced pressure tank 9, so that the pressure inside this preliminary reduced pressure tank 9 may also be reduced by opening the exhaust valve 23.

The lower end of the said communicating tube 7 is connected for communication with the material inlet 31 of the main drying tank 30. This main drying tank 30 is provided on its circumferential wall with a heat preserving heater 33. Moreover, a branch exhaust pipe 24 is connected to the top plate of the main drying tank 30 and the other end of this branch exhaust pipe 24 is connected with the said exhaust pipe 21 so that the pressure inside this main drying tank 30 may also be reduced with the action of the suction air source 20 in the same way as the said reduced pressure drying tank 1 and the preliminary reduced pressure tank 9. The powdered or granular materials dried to the prescribed moisture percentage in the main drying tank 30 are discharged to the subsequent process from a material outlet 32 through an airtight rotary feeder 34. The symbol 12 indicated in the drawing represents a level meter, 13 is a drive source such as motor which turns an agitating means 5 mounted on a rotary shaft 14, and 15 is a temperature sensor.

Now the actions of this embodiment will be described hereunder.

With the material valve 8_2 closed, the material valve 8_1 opens to supply the powdered or granular materials from the supply source of materials 11 to inside the preliminary reduced pressure tank 9 up to the upper limit value of the level meter 12 and closes when the tank is filled with the prescribed volume of powdered or granular materials.

Next, the exhaust valve 23 which was closed opens to reduce the pressure inside the preliminary reduced pressure tank 9 to the prescribed pressure (100 - 200 Torr for example, but not limited to this value).

On the other hand, both the reduced pressure drying tank 1 and the main drying tank 30 are depressurized in advance to the prescribed pressure (100 - 200 Torr for example, but not limited to this value).

In this state, the material valve 8_2 opens to supply the powdered or granular materials from the preliminary reduced pressure tank 9 to the reduced pressure drying tank and then closes. Under this depressurized state, electromagnetic waves such as microwave are irradiated from the electromagnetic wave generator 2 on the powdered or granular materials inside the reduced pressure drying tank 1 while the materials are being agitated with the operation of the drive source 13. The powdered or granular materials are heated with electromagnetic waves until the materials reach the prescribed temperature while measuring the material temperature with the temperature sensor 16 of the reduced pressure drying tank 1. The water content vaporized from the materials during this heating is discharged from the suction air source 20 through the material inlet 4 and the exhaust pipe 21.

If the materials reach the prescribed temperature, the electromagnetic wave generator 2 stops working and the material valve 8_3 opens to inject the powdered or granular materials from the reduced pressure tank 1 into the main drying tank 30 and then closes. The above process is performed repeatedly in linkage with the level meter 35 of the main drying tank 30.

Since the inside of the main drying tank 30 is maintained at the prescribed temperature with the heat preserving heater 33 and the temperature sensor 15, the materials injected inside the main drying tank 30 are dried under a reduced pressure while maintaining the temperature obtained as a result of heating in the reduced pressure drying tank 1. And the water content evaporated from the materials inside the main drying tank 30 is discharged through the branch exhaust pipe 24 with the suction force of the suction air source 20.

The materials dried to the prescribed moisture percentage are discharged from the rotary feeder 34 to the subsequent process in accordance with the request from the subsequent process.

It is also possible to adopt a construction designed to supply the preliminary reduced pressure tank 9 in powdered or granular materials under the atmospheric pressure without connecting the branch exhaust pipe 22 and the exhaust valve 23 to it and depressurize the reduced pressure drying tank 1. In that case, a closing valve (not illustrated) will be provided at a proper point on the discharge tube 21.

In Fig. 1, a construction without the material valve 8_1, the preliminary reduced pressure tank 9, the branch exhaust pipe 22 and the exhaust valve 23 can also be adopted. In that case, a level meter (not illustrated) will be provided on the reduced pressure drying tank 1.

Fig. 2 indicates the 2nd embodiment.

This construction is characterized in that separate suction air sources 20 are provided for the reduced pressure drying tank 1 and the main drying tank 30 and that the reduced pressure drying tank 1 and the main drying tank 30 are made to work at different pressures.

According to this construction, the pressure in the reduced pressure tank 1 cannot be made very low because microwaves produce an electric discharge at the irradiation port under a reduced pressure of 100 Torr or under. Therefore, this construction can be applied by reducing the pressure in the main drying tank 30 to 1 - 10^{-3} Torr or so for example in case the drying speed is insufficient or the final moisture percentage is insufficient at the pressure exerted on the reduced pressure drying tank 1 and the main drying tank 30 (100 - 200 Torr, for example) in Fig. 1.

Fig. 3 indicates the 3rd embodiment.

This construction is characterized in that the construction from the supply source of materials 11 to the main drying tank 30 is the same as that in Fig. 2 while only the reduced pressure tank 1 is depressurized without depressurization in the main drying tank 30 and that a dehumidifying and drying system 40 having a known honeycomb type dehumidifying rotor, etc. is connected to the main drying tank 30.

Namely, the air dehumidified in the dehumidifying and drying system 40 is made to pass through a dehumidified air supply pipe 41 and heated by a heater 42 which also serves as heat preserving heater, and that dehumidified hot air is supplied into the main drying tank 30. 43 is a temperature sensor. To the top part of the main drying tank 30, one end of an exhaust pipe 24 is connected to discharge the exhaust gas from inside the main drying tank 30 while the other end of this exhaust pipe 24 is connected to the said dehumidifying & drying system 40.

This embodiment provides such advantages as reduction of equipment cost because an existing main drying tank 30 provided with the dehumidifying and drying system 40 can be used as it is.

The purpose of submitting the powdered or granular materials to dielectric heating under a reduced pressure with electromagnetic waves such as microwave, etc. from an electromagnetic wave generator in the reduced pressure drying tank 1 is to increase the temperature of the powdered or granular materials but this heating process also serves for crystallization in the case of powdered or granular materials of plastic materials such as non crystallized polyethylene terephthalate, etc.

Claims

1. A method of drying powdered or granular material, which comprises subjecting the material to (a) a heating process in which the material is heated to a desired temperature under reduced pressure by means of electromagnetic waves, and to (b) a heat insulating process in which the heat is preserved so as to perform final drying.

2. A method as claimed in claim 1, wherein the heat insulating process is carried out under reduced pressure.

3. A method as claimed in claim 1 or 2, wherein the electromagnetic waves are microwaves.

4. An apparatus for drying powdered or granular material, comprising:

   a reduced pressure drying tank (1) having an electromagnetic wave generator (2) for performing dielectric heating of the powdered or granular material supplied through a material inlet (4);

   a main drying tank (30) communicating with a material outlet (6) of said reduced pressure drying tank (1) through a communicating line (7) and having a heat preserving heater (33); and

   a suction air source (20) for depressurizing at least said reduced pressure drying tank (1).

5. An apparatus as claimed in claim 4, wherein the main drying tank (3) is able to be depressurized by the suction air source (20).

6. An apparatus as claimed in claim 4, comprising a separate suction air source (20) for depressurizing the main drying tank (30).

7. An apparatus as claimed in any of claims 4 to 6, wherein a preliminary reduced pressure tank (9) is provided on the upstream side of the reduced pressure drying tank (1) so that the preliminary reduced pressure drying tank (9) may also be depressurized by the suction air source (20).

8. An apparatus as claimed in claim 7, wherein the suction air source (20) for the preliminary reduced pressure drying tank (9) is common with at least that for the reduced pressure drying tank (1).

9. An apparatus as claimed in any of claims 4 to 8, wherein the electromagnetic wave generator (2) is a generator of microwaves.

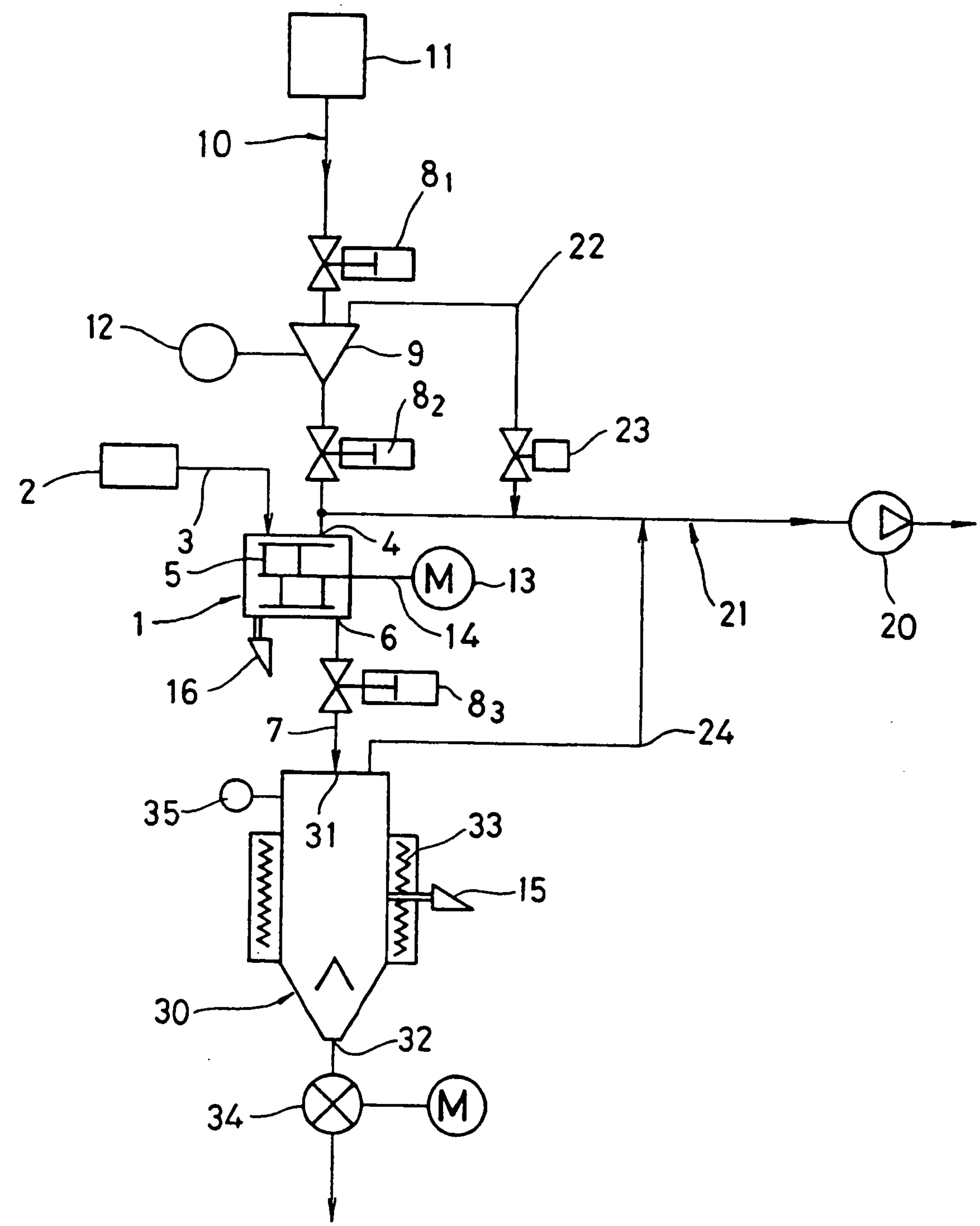
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FIG. 1

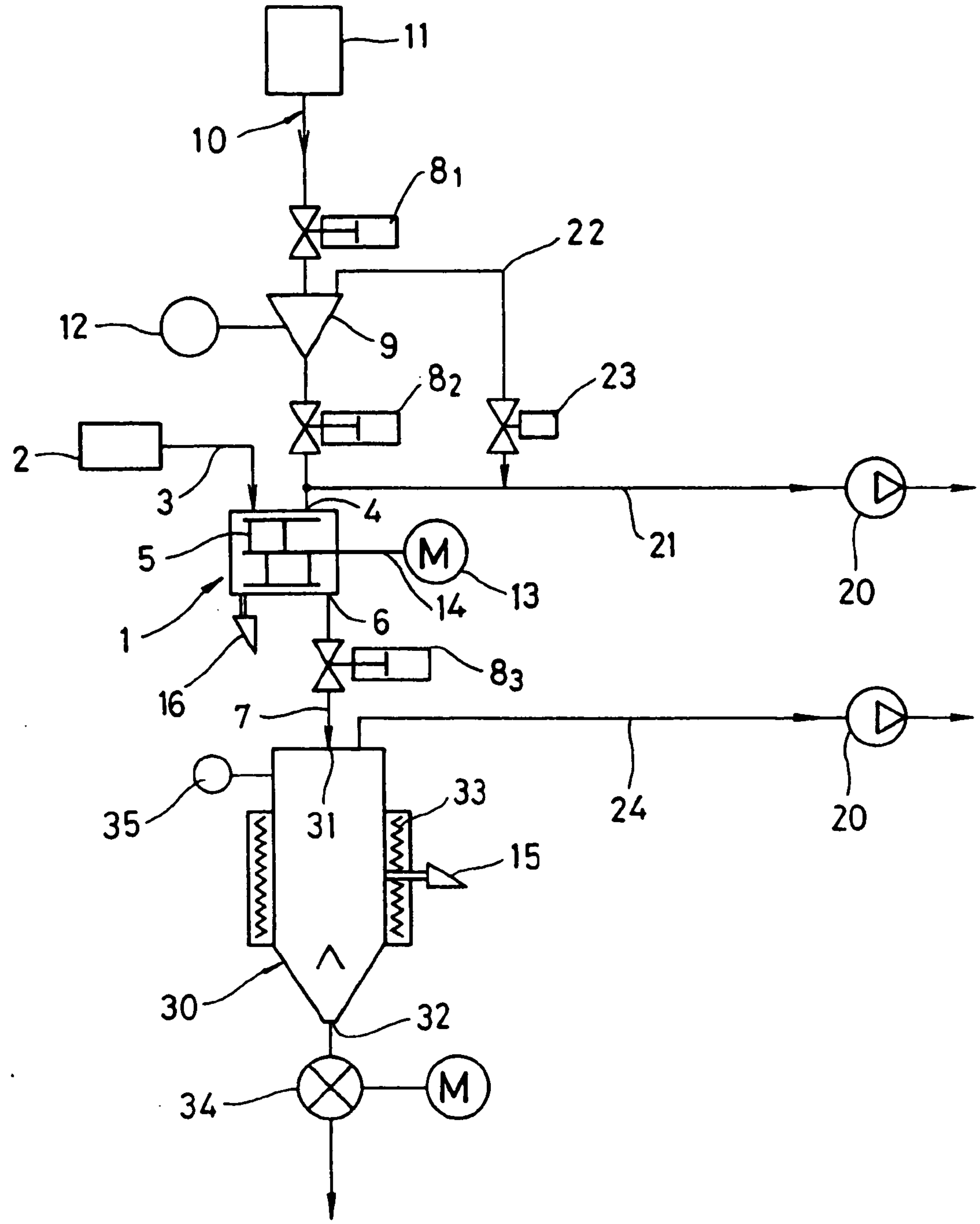
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FIG. 2

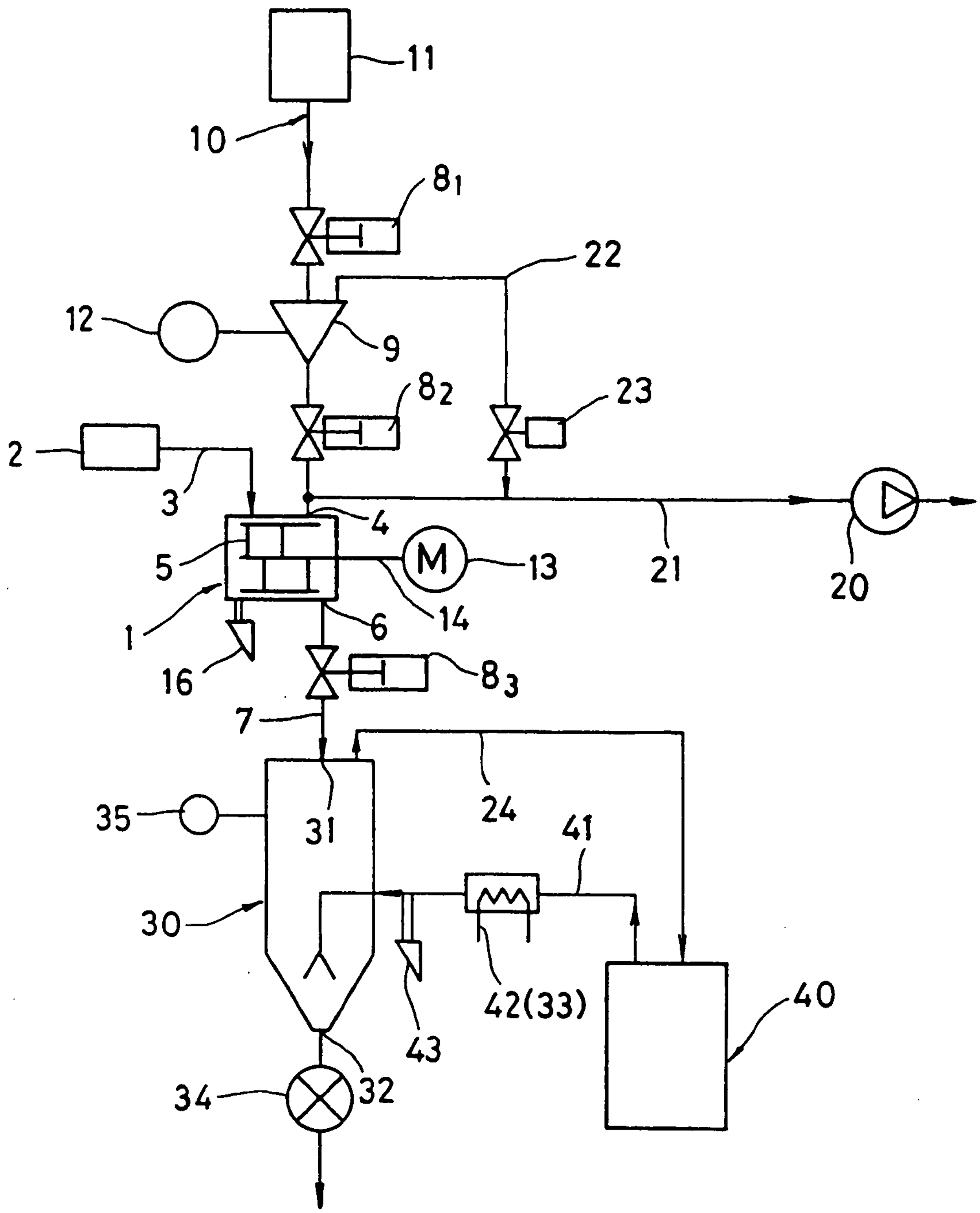
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FIG. 3

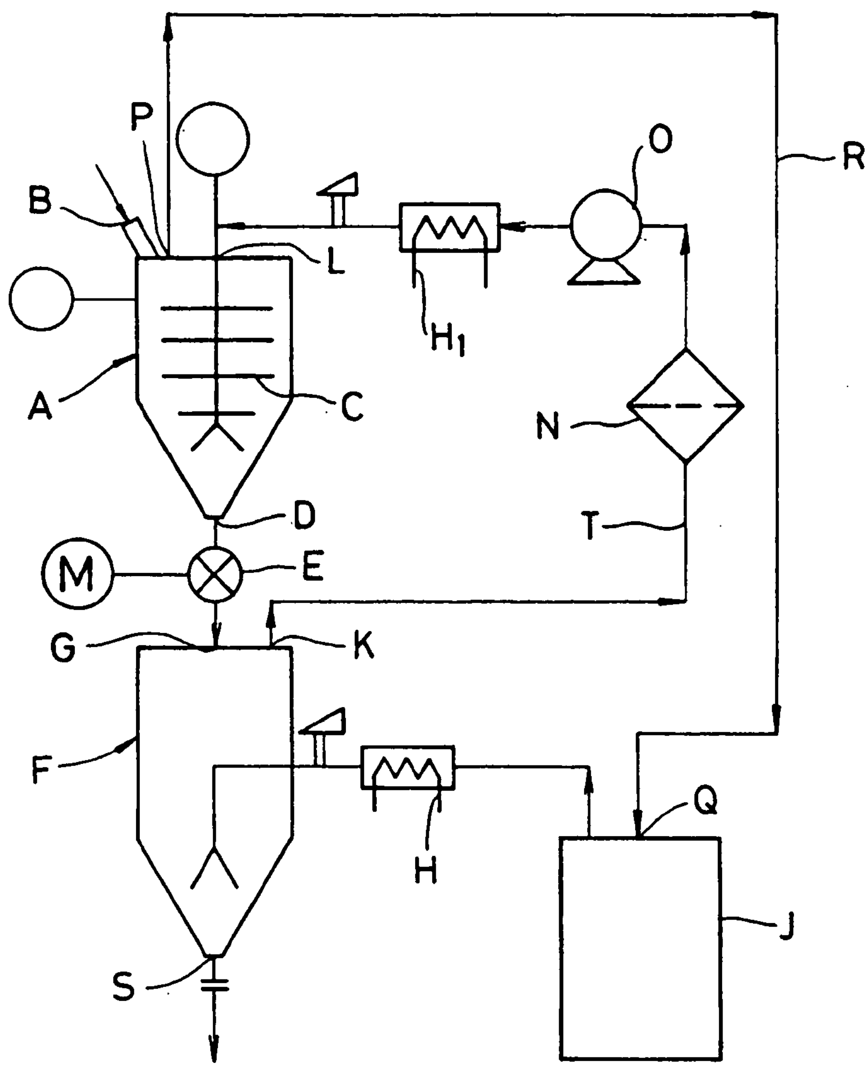

FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 5787

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	WO-A-8 201 062 (TILLIT ET AL) * the whole document * ---	1-5,9	F26B7/00
X A	US-A-4 347 670 (WEAR ET AL) * the whole document * ---	1-3 4-9	
A	US-A-4 882 851 (WENNERSTRUM ET AL) * the whole document * ---	1-4,9	
A	FR-A-1 398 016 (SOGEV) ---		
A	FR-A-1 381 525 (SOGEV) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F26B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 SEPTEMBER 1991	SILVIS H.

CATEGORY OF CITED DOCUMENTS

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